

## REVIEW ARTICLE

# POTENTIAL OF ENTOMOPATHOGENIC FUNGI FOR THE CONTROL OF MEDITERRANEAN FRUIT FLY (DIPTERA: TEPHRITIDAE): A REVIEW

Dikshya Subedi<sup>a\*</sup>, Pratima Bagale<sup>a</sup>, Toyannath Joshi<sup>b</sup>, Pradip Regmi<sup>a</sup>, Sarad Pokhrel<sup>a</sup>

<sup>a</sup>Agriculture and Forestry University, Rampur, Chitwan, Nepal.

<sup>b</sup>Ministry of Agriculture and Livestock Development, Singhadarbar, Kathmandu.

\*Corresponding author's mail: [dikshya.subedi11@gmail.com](mailto:dikshya.subedi11@gmail.com)

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## ABSTRACT

Fruit flies are one of the most harmful pests with over 300 different hosts as it causes extensive damage to fruits and vegetables. The economic importance of this pest is something to be concerned about and efforts to control it are necessary as it is evident by the reports of almost 90% loss of yields in several fruits and vegetables. Being an insect that has a complete metamorphosis, it goes through the phases of egg, larvae, pupae and adult. Among different methods of controlling fruit flies, the bio-control approach is also one which is used widely and has been successful across several countries like Japan to control and lower down the level of fruit flies population to a more acceptable level. The bio-control approaches include bio-pesticides, entomophagous nematodes, parasitoids, predators and sterilizing male techniques whose efficacy are demonstrated by several instances in which they proved to be successful in several academic writings.

## KEYWORDS

Bio-control, bio-pesticides, economic, entomophagous, predators

## 1. INTRODUCTION

Fruit flies belong to the Tephritidae family, which has 4,000 species worldwide, 350 of which are economically important (Asian Fruit Fly IPM Project, 2011). Tephritid fruit flies can directly harm fruits and vegetables, causing yield losses of up to 90%, depending on the population, type, location, and season of the fruit fly. Due to the strict quarantine regulations enforced by the majority of importing countries, fruit fly infections can cause significant losses in trade value and export potential in addition to direct losses (Plant Health Australia, 2011). For proper management and quarantine regulation, it is necessary to have knowledge of and be able to identify between several species of fruit flies (Sharma et al., 2015). Fruit fly from the Mediterranean *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae) is an economically important fruit fly pest that attacks over 300 different hosts (Papadopoulos et al., 2001).

The Mediterranean fruit fly is native to east central Africa, but it has spread among many nations throughout the world, wreaking havoc on fruit growers. The Mediterranean fruit fly's great adaptability to a variety of invaded settings, as well as its multivoltinism and polyphagy, make it a severe danger to fruit production (Beris et al., 2015). It is an economic insect pest attacking the fruits of mangoes, apricots, guava, citrus, and peaches, olive, cherry, almond, grapes, fig, loquat, cucurbits, tomatoes, horticulture and vegetable sectors, causing large losses to fruits all over the world (Vargas et al., 2012). Fruit flies are relatively small (2.5-10mm), often colorful insects belonging to the family Tephritidae (Diptera). They are almost cosmopolitan in distribution found in Europe, America, Canada, the Mediterranean region, the Middle East, Asia, and Africa (Kamali et al., 2013).

Mediterranean fruit fly (medfly, *Ceratitis capitata*, Diptera: Tephritidae) is one of the most destructive agricultural pests in the world, having a broad host plant range that includes over 260 different fruits, vegetables, and nuts (Papanicolaou et al., 2016; Dias et al., 2018). The larvae pose a serious

quarantine risk to both domestic and foreign markets in addition to destroying infected fruit. Polyphagy, superior mobility, dispersive powers, and high reproductive rates are common traits of invasive *Bactrocera* species. To date, a total of 70 fruit fly species are considered as important agricultural pests (Garcia and Ricalde, 2013). Crop injury resulting from fruit flies is due to oviposition in fruit and soft tissues of vegetative parts of certain plants, feeding by the larvae, and decomposition of plant tissue by invading secondary microorganisms (Molina et al., 2010).

In Kenya alone, ~90 000 tons of mangoes are produced annually but an estimated 20- 40% of the fruit is lost to fruit fly infestation at the time of ripening (Ekesi et al., 2002). Economic losses due to fruit flies exceed two billion dollars worldwide (Garcia and Ricalde, 2013). The current practices adopted by the growers worldwide to keep the fruit flies under the economic threshold level are insecticidal treatment of the soil, dipping of fruits in insecticide, spraying the crop with insecticide, using the protein bait mixed with insecticide, of them, focus relies on the use of pesticides especially on the organophosphates (Kamali et al., 2013); spinosad and deltamethrin (Sirjani et al., 2009). However, there are a number of environmental issues related to the use of synthetic pesticides, such as diazinon, for pest management, including environmental contamination, harm to non-target organisms, and the emergence of resistance (Ekesi et al., 2002).

Finding biological control alternatives, such as entomopathogenic bacteria, nematodes, and fungi, has been prompted by the current social and environmental issues related to the use of insecticides for fruit fly control, either by aerial or ground applications on foliage for adult control or to the soil for larvae or recent emerged adult control (Toledo et al., 2008). Though many studies have been carried out for biocontrol method for fruit flies; however, their efficacy is largely unknown. This review aimed to examine the potential of entomopathogenic fungus against fruit flies. We examined the efficacy of biocontrol methods, find out the

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successful combination of different biocontrol, come up with the most appropriate solution and finally we explored the area of biocontrol which has potential if further research is needed.

Taxonomic position (Sharma et al., 2015):

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Diptera

Family: Tephritidae

Subfamily: Dacinae

Tribe: Dacini

Genus: Bactrocera

## 2. LIFE CYCLE OF FRUIT FLY

### 2.1 Eggs

Female fruit flies lay their eggs beneath the fruit's skin with the assistance of a sharp ovipositor. During her lifetime, a fruit fly typically lays 500-700

eggs. It takes roughly 2-5 minutes to lay a batch of six to twenty eggs into the host. Fruit flies lay white, slender eggs that are about 1mm long and develop in 1-2 days at 26 °C. Because of the presence of sting marks, the eggs are plainly visible on apples and loquats, making them difficult to identify on vegetable crops (Ekman, 2015).

### 2.2 Larvae

When the larvae hatch, they are less than 2 mm long and have no legs. They mature in about 2 weeks at 26°C, attaining a length of 5-9 mm in the summer and 45 days in the winter. Their larvae have a creamy color and guts that are colored by the food they eat (Sookar, 2013). Their larvae can do a lot of damage since they can easily feed beneath the fruit skin, where the damage is not visible. Sunken or discolored patches are the most visible symptoms. Magots crawl into the center of stone fruit and apples, for example, causing the fruit to turn dark and slimy (Ekman, 2015).

### 2.3 Pupae

When the larvae are fully grown, they consume the fruit pulp before descending to the ground and digging tunnels beneath the surface. After becoming pupae, the larvae pass away in the earth. The pupae have the appearance of huge grains of brown rice (Ekman, 2015). The larvae must reassemble themselves inside their pupal case for 10 days before they can emerge as a fly. When the baby fly is ready to emerge, it tears the top off the pupal case and scurries to the soil surfaces (Sookar, 2013).

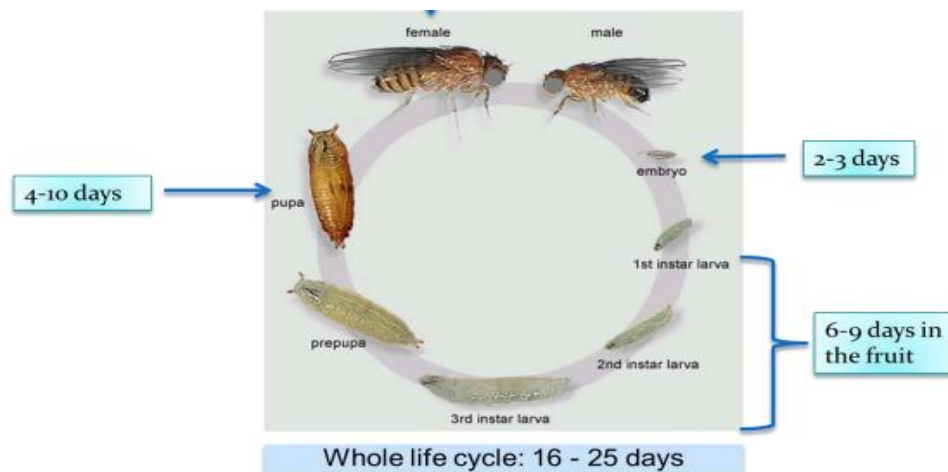


Figure 1: Life Cycle of Fruit fly (Asian Fruit Fly IPM Project, 2011)

### 2.4 Adult

The pupae develop into adults (flies) and emerge from the ground, spreading their new wings and sipping water. It will perish in less than 48 hours if it is not given water. Nectar, juice from damaged fruit, honey dew, and exudates on leaves are some of the liquid foods they eat in nature. To become sexually mature, they eat protein. Males and females both eat, but the more protein a female has, the more eggs she can lay. Flies reach sexual maturity 10-14 days after emerging and begin looking for a mate. Females can mate only once or multiple times. If their first mate isn't fit, they will mate again. Female flies have a protruding ovipositor, whereas males have a rounded abdomen, allowing female flies to store sperm for weeks. She looked for a host to lay eggs after she mated. Lemons and grapes were her favorite hosts. Male wings are typically larger and shorter than female wings, which have a band running across the middle of the wings with dark streaks and spots within the wing cells. The thorax is a creamy white to golden color with a black blotch pattern, while the abdomen is brown with fine black bristles on the dorsal side and two light bands on the basal half. It completes its life cycle in 21 to 30 days (Sookar, 2013).

## 3. BIOCONTROL APPROACHES FOR MANAGEMENT OF FRUIT FLIES

### 3.1 Biopesticide

The wastewater from the olive mill contains polyphenolic fractions that have the potential to be employed as a potent natural chemosterilant against Mediterranean fruit flies, as well as a potential ovidical agent (Ilio and Cristofaro, 2020).

### 3.2 Entomopathogenic Nematodes

It has been documented that several entomopathogens, such as

nematodes, bacteria, viruses, and fungi, infect different tephritid species. Entomopathogenic nematodes (EPNs) are simply sprayed using standard spraying equipment, have a wide host range, and have a high reproductive potential. According to a study, the worm *Steinernema feltiae* Filipjev was found to be vulnerable to late third instars of *C. capitata*, *B. cucurbitae*, and *B. dorsalis* in laboratory testing (Sookar, 2014). The Steinernematidae and Heterorhabditidae have drawn the most attention out of all the EPNs investigated for biological control of insects because they have been used as classical, conservational, and augmentative biological control agents and because they share many characteristics with other effective biological control agents (Lacey and Georgis, 2012).

EPNs of the genera *Heterorhabditis* and *Steinernema* linked to certain bacteria (of the genera *Xenorhabdus* and *Photorhabdus*) are effective bio-control agents for a variety of insect pests, including foliar pests and those that spend a portion of their life cycle in the soil or cryptic environments (Saleh et al., 2018). Over 77% of the adult *B. zonata* were killed by *Heterorhabditis marelatus* D1 after 48 hours of the adults emerging from their pupae, demonstrating the species' high effectiveness in controlling adult *B. zonata* (Saleh et al., 2018). While in the field, the average larval mortality rate utilizing *Heterorhabditis baujardi* LPP7 was 87.43%, in the laboratory, the parasite killed 90% of *C. capitata* larvae and more than 80% of pupae (Minas et al., 2016).

### 3.3 Predators

Fruit flies of various stages are known to be attacked by a variety of predators from the families Formicidae, Dermoptera, Staphylinidae, Carabidae, Coccinellidae, Chrysopidae, Pentatomidae, and Coreidae (Bateman, 1972; Fletcher, 1987; Stibick, 2004). Predators can somewhat lower fruit fly populations even if they are not known to be good fruit fly controllers (Debouzie, 1989). Adult fruit flies have been observed to be

preyed upon by spiders, wasps, ants, birds, toads, and gekkos (Fletcher, 1987; Hendrichs et al., 1994). According to Drew, after consuming infected fruit, predators like birds and primates significantly lower the population of fruit flies in Australia's endemic forest (Drew, 1987).

### 3.4 Parasitoids

Fruit fly parasitoids are classified into several families: Eulophidae, Chalcididae, Pteromalidae, Cynipidae, and Braconidae (Stibick, 2004). For traditional biological control, fruit flies are not desirable targets. Foraging, they spread out far, leaving parasitoids in their wake. Hawaii has produced the most published studies on the use of parasitoids to control fruit fly populations. *Fopius arisanus* (Sonan), *F. vandenboschi* (Fullaway), *Diachasmimorpha longicaudata* Ashmead and *D. tryoni* (Cameron) (hosts: Oriental and/or Mediterranean fruit fly), and *Psytalia fletcheri* (host: melon fly) are the significant fruit fly parasitoids that are now discovered. The parasitoids that are most frequently utilized include *Ac. indica*, which was initially found in India by Compere, and *D. longicaudatus*, which is a parasitoid of dacines in SouthEast Asia (Compere, 1912; Gilstrap and Hart, 1987; Wharton and Gilstrap, 1983). The parasitoids that were introduced for the Medfly in Costa Rica were later discovered to be more commonly linked to *Anastrepha* spp., with 5.5% versus 10.5% parasitization, respectively (Jiron and Mexzon, 1989; Wharton and Gilstrap, 1983). The greatest options for effectively controlling medflies biologically are still most likely hymenopterous parasitoids.

### 3.5 Sterile Insect Technique

The sterile insect technique (SIT) is a pest management approach that lowers the fertility of a field population of the same species by deploying sterile insects throughout a certain region in an inundative manner. The SIT is currently used extensively to control tephritid fruit flies. Preventive, containment, eradication, and suppression are the strategy choices in an integrated pest management program for fruit flies that integrates the SIT (Enkerlin, 2005). According to a study, the first extensive program was put in place in the 1970s and prevented the spread of *C. capitata* from Central America into southern Mexico. To remove *B. cucurbitae* from Okinawa and all of the country's southwest islands, the SIT was used in Japan (Hendrichs et al., 1983; Kuba et al., 1996).

Nevertheless, this approach is species-specific, involves substantial resources, and depends on the capacity to raise millions of flies for release. Millions of fruit flies are raised and then sterilized using gamma or x-rays. Subsequently, the sterile males are dispersed twice a week at a density of 100,000 to 300,000 per square kilometer in the designated locations. They mate with wild females and lay sterile eggs as a result. The natural population then decreases, assuming that other complimentary fruit fly management measures are appropriately implemented. To mate with females, sterile males compete with wild males. Wilder females must mate with sterile men and not wild ones, as sterile males are less competitive than wild males. This means that a large "flooding" ratio of sterile males to wild males is necessary.

## 4. CONCLUSION

Fruit flies acquire the ability to increase their population at alarming rates with destructive capacity due to their ability to adapt and infest a wide range of hosts which includes apple, pear, mango, guava, citrus, olive, cherry, almond, grapes, fig, loquat, cucurbits, tomatoes, etc. The insect undergoes a complete metamorphosis life cycle. After a thorough review of numerous academic papers, the bio-control method has been deemed as one of the successful methods. Olive mill wastewater is considered a potential bio-insecticide while other organisms like entomopathogenic nematodes, predatory insects, and parasitoid organisms belonging to various families have also been found effective as a means of bio-control for this pest.

### AUTHOR DECLARATION

The authors declare no conflicts of interest. All authors contributed equally in all stages of the preparation of this manuscript. Similarly, the final version of the manuscript was approved by all authors.

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